CLAIMS

Sub B1

1. A method of determining an acoustic velocity in a segment of a bone covered with a layer of soft tissue having an outer surface, comprising:

determining a first travel time of a first ultrasonic wave along a first path from said outer surface back to said outer surface which path includes at least a first part of said bone segment;

determining a second travel time of a second ultrasonic wave along a second path from said outer surface back to said outer surface which path includes at least a second part of said bone segment;

determining a third travel time of a third ultrasonic wave along a third path from said outer surface back to said outer surface which path includes at least a third part of said bone segment; and

deriving said acoustic velocity in said segment of bone from said three determined travel times,

wherein said paths each start at a start point and end at an end point and wherein said start and end points are not collinear.

2. A method according to claim 1, wherein at least two of said first, second and third waves are generated simultaneously by a single transmitter.

3. A method according to claim 1 ~~or claim 2~~, wherein at least two of said first, second and third waves are detected simultaneously by a single receiver.

a 4. A method according to ~~any of claims 1-3~~ claim 1, wherein at least two of said first, second and third waves each have an average frequency that is substantially the same, when generated.

a 5. A method according to ~~any of claims 1-4~~ claim 1, wherein at least two of said first, second and third waves each have an average frequency that is substantially different, when generated.

a 6. A method according to ~~any of claims 1-4,~~ claim 1 wherein at least two of said first, second and third waves each have an average frequency that is substantially different, when detected.

7. A method according to ~~any of claims 1-5,~~ claim 1, wherein at least two of said first, second and

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third waves each have an average frequency that is substantially the same, when detected.

claim 1

8. A method according to ~~any of claims 1-7~~, wherein each of said first, second and third paths comprises soft tissue portions and wherein at least two of said first, second and third paths have an overlap of at least 20% over the length of their soft tissue portions.

a

claim 1

9. A method according to ~~any of claims 1-7~~, wherein each of said first, second and third paths comprises soft tissue portions and wherein at least two of said first, second and third paths have an overlap of at least 30% over the length of their soft tissue portions.

a

claim 1

10. A method according to ~~any of claims 1-7~~, wherein each of said first, second and third paths comprises soft tissue portions and wherein no two of said first, second and third paths overlap by more than 20% of the length of their soft tissue portions.

a

claim 1

11. A method according to any of ~~claims 1-7~~, wherein each of said first, second and third paths comprises soft tissue portions and wherein no two of said first, second and third paths overlap by more than 30% of the length of their soft tissue portions.

a

claim 1

12. A method according to ~~any of claims 1-11~~, wherein at least two of said first, second and third bone parts overlap at least 20% over their length.

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claim 1

13. A method according to any of ~~claims 1-11~~, wherein at least two of said first, second and third bone parts overlap at least 40% over their length.

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claim 1

14. A method according to ~~any of claims 1-11~~, wherein at least two of said first, second and third bone parts overlap at least 70% over their length.

a

claim 1

15. A method according to ~~any of claims 1-11~~, wherein no two of said first, second and third bone parts overlap by 20% or more of their length.

a

claim 1

16. A method according to ~~any of claims 1-11~~, wherein no two of said first, second and third bone parts overlap by 40% or more of their length.

a

claim 1

17. A method according to ~~any of claims 1-11~~, wherein no two of said first, second and third bone parts overlap by 20% or more of their length.

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third bone parts overlap by 70% or more of their length.

18. A method according to ~~any of claims 1-17~~ claim 1, comprising estimating a soft tissue velocity and wherein deriving said acoustic velocity comprises deriving said bone velocity using said estimated soft tissue velocity.

19. A method according to ~~any of claims 1-17~~ claim 1, comprising determining a fourth travel time of a fourth ultrasonic wave along a fourth path from said outer surface back to said outer surface which path includes at least a fourth part of said bone segment and wherein deriving said acoustic velocity comprises deriving a bone velocity also using the fourth travel time.

20. A method according to ~~any of claims 1-19~~ claim 1, wherein geometric projections of at least two of said acoustic wave paths onto the outer surface are parallel.

21. A method according to ~~any of claims 1-19~~ claim 1, wherein no geometric projections of said acoustic wave paths onto the outer surface are parallel to each other.

22. A method according to any of claim~~s~~ 1~~-19~~, wherein said acoustic waves are generated and detected by ultrasonic elements at end faces thereof and wherein said end faces are not coplanar.

23. A method according to any of claim~~s~~ 1~~-22~~, wherein said outer surface is not parallel to an outer surface of said bone, while said waves travel through said bone.

24. A method according to ~~any of~~ claim~~s~~ 1~~-23~~, wherein deriving comprises solving a set of simultaneous equations.

25. A method according to ~~any of~~ claim~~s~~ 1~~-24~~, comprising, repeating said determining of travel times and said deriving of acoustic velocity for a plurality of bone segments, to generate a map of acoustic bone velocity of at least a portion of a bone.

26. A method according to any of claim~~s~~ 1~~-25~~, comprising, repeating said determining of travel times and said deriving of acoustic velocity for a plurality of orientations of travel of said waves through said bone, to generate a map of directional acoustic bone velocity of at least a

portion of a bone.

27. A method of determining at least one of a set of unknowns, including an acoustic bone velocity, soft tissue velocity, a thickness of said soft tissue and an inclination angle of an outer surface of said soft tissue relative to the bone, comprising:

determining the travel time of at least three ultrasonic waves which travel from said surface, to said bone, along the surface of said bone and back to said surface;

assuming a value for at least one of said unknowns; and

deriving, by solving a set of simultaneous equations, at least one of said unknowns from said three determined travel times and from said assumed value.

28. A method according to claim 27, wherein said assumed unknown comprises a soft tissue velocity.

29. A probe for acoustic bone velocity measurement, comprising:

at least four ultrasonic elements, at least one of which comprises a transmitter and at least one of which comprises a receiver, wherein said ultrasonic elements are not all collinear; and

a controller which controls said at least one transmitter to transmit at least three ultrasonic waves through a layer of soft tissue to a bone, which controller detects via said at least one receiver, at least relative travel times of said three waves, after they travel along a surface of said bone and which controller derives an acoustic bone velocity from said determined at least travel times.

30. A probe according to claim 29, wherein said at least four ultrasonic elements comprise three transmitters and one receiver.

31. A probe according to claim 29, wherein said at least four ultrasonic elements comprise three receivers and one transmitter.

32. A probe according to claim 29, wherein said at least four ultrasonic elements comprise two receivers and two transmitters.

9 33. A probe according to ~~any of claims 29-32~~ claim 29, wherein all of said ultrasonic elements are

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coplanar.

34. A probe according to ~~any of~~ claim~~s~~ 29~~-32~~, wherein not all of said ultrasonic elements are coplanar.

35. A probe according to ~~any of~~ claim~~s~~ 29~~,34~~, wherein said probe comprises a surface adapted to be urged against a skin layer of a soft tissue and wherein said ultrasonic elements are inclined relative to said surface at an inclination angle.

36. A probe according to claim 35, wherein said inclination angle is determined responsive to an expected acoustic bone velocity.

37. A probe according to ~~any of~~ claim~~s~~ 29~~,36~~, wherein said at least three ultrasonic waves are generated by a single transmitter as a single wave, which wave scatters to form said at least three waves.

38. A probe for acoustic velocity determination, comprising:

at least two ultrasonic elements, at least one of which comprises a transmitter and at least one of which comprises a receiver; and

a plurality of staggered acoustic barriers which significantly attenuate ultrasonic waves which travel along a direct line in said probe between said transmitter and said receiver.

39. A probe according to claim 38, wherein volumes in said probe between said at least one transmitter, said at least one receiver and said barriers comprise an ultrasonic attenuating filler.

40. A probe according to claim~~s~~ 38 ~~or claim 39~~, comprising electrical shielding for said at least one receiver and at least one transmitter.

41. A probe according to ~~any of~~ claim~~s~~ 38~~-40~~, comprising at least two additional ultrasonic elements, which elements are also acoustically separated by said barriers.

42. A probe according to ~~any of~~ claim~~s~~ 38~~-41~~, wherein said probe is adapted for acoustic bone velocity determination.

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43. A probe according to ~~any of~~ claim~~s~~ 38~~-42~~, wherein an acoustic chamber is defined as being bordered by said at least transmitter and said at least receiver and a plane to be placed against a body, wherein said acoustic chamber is filled with an acoustically attenuating material.

44. An ultrasonic probe comprising:

at least two ultrasonic elements, at least one of which comprises a transmitter and at least one of which comprises a receiver; and

an acoustic chamber defined as being bordered by said at least transmitter and said at least receiver and a plane to be placed against a body,

wherein said acoustic chamber is filled with an acoustically attenuating material.

45. A probe according to ~~any of~~ claim~~s~~ 29~~-44~~, wherein said ultrasonic elements are comprised in an ultrasonic element grid.

46. A probe according to claim 45, wherein said probe scans a bone by electrically scanning said grid.

47. A probe according to ~~any of~~ claim~~s~~ 29~~-46~~, wherein at least one of said ultrasonic elements comprises a phased array.

48. A probe according to claim 47, wherein an inclination angle for said phased array elements is achieved by electrically controlling said phased array.

49. A probe according to ~~any of~~ claim~~s~~ 29~~-48~~, comprising a memory device attached to said probe, wherein calibration data for said probe are stored on said memory device.

50. A probe according to claim 49, wherein said calibration data comprises at least one distance between ultrasonic elements.

51. A probe according to claim 49 ~~or 50~~, wherein said calibration data comprises at least one vertical separation of an ultrasonic element.

52. A probe according to claim 49 ~~or 50~~, wherein said calibration data comprises at least

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one vertical separation of a path between two of said ultrasonic elements.

53. A probe according to ~~any of~~ claim~~s~~ 49~~-52~~, wherein said calibration data comprises a late cutoff time, after which received waves are ignored.

54. A probe according to ~~any of claims~~ claim 49~~-53~~, wherein said calibration data comprises an acoustic velocity of a portion of the probe between at least one of said ultrasonic elements and a surface against which said probe is urged in use.

55. A method of rejecting parasitic signals in an acoustic bone velocity probe, comprising:

detecting signals arriving at a receiver, from a transmitter, ostensibly after the signal traveled through a portion of bone, wherein detecting a signal comprises detecting a first wave arriving at the receiver from the transmitter; and

rejecting said signal if said signal arrives after a predetermined time limit, associated with waves which do not travel through the bone.

56. A method according to claim 55, wherein said signal is rejected if it arrives before a second time limit.

57. A method according to claim 55 ~~or claim 56~~, wherein said predetermined time limit is determined based on a calibration of the probe.

58. A method of detecting the arrival of an ultrasonic wave from a bone, in the presence of waves traveling substantially only through soft tissue, comprising:

acquiring a signal representative of said bone wave and said soft-tissue waves; and

analyzing said signals to detect changes in amplitude in at least one frequency in said signal, which changes are associated with said wave from said bone.

59. A method according to claims 58, wherein said analyzing comprises determining a significant increase in amplitude of the signal, when a wave arrives from a bone.

60. A method of detecting a delay in the arrival of ultrasonic waves from a bone, in the presence of waves traveling substantially only through soft tissue, comprising:

acquiring a signal representative of one arriving bone wave and soft tissue waves;

acquiring a signal representative of another arriving bone wave and soft tissue waves; and

correlating the two signal to determine a relative difference in travel times of the one wave and the another wave.

61. A method according to claim 60, wherein said correlation is performed responsive to the generation of said one arriving wave.

62. A method according to claim 61, wherein said correlation is performed responsive to an expected arrival time window of said one arriving wave.

63. A method of acoustic bone velocity determination, comprising:

urging an acoustic bone velocity probe onto the surface of a soft tissue layer and not parallel to an underlying bone surface;

transmitting at least one wave to said bone surface and receiving at least two waves from said bone surface, wherein said received waves are waves that are not reflected from said surface;

measuring a travel time for each of said received waves; and

deriving said acoustic bone velocity from said measured travel times.

64. A method of acoustic bone velocity determination, comprising:

urging an acoustic bone velocity probe onto the surface of a soft tissue layer and not parallel to an underlying bone surface;

transmitting at least one wave from said probe to said bone surface and receiving at least two waves from said bone surface, wherein waves are transmitted and received from locations in the probe, which transmission and reception locations are not coplanar;

measuring a travel time for each of said received waves; and

deriving said acoustic bone velocity from said measured travel times.

65. A method of acoustic bone velocity determination, comprising:

urging an acoustic bone velocity probe onto the surface of a soft tissue layer and not parallel to an underlying bone surface;

transmitting at least one wave to said bone surface and receiving at least two waves from said bone surface, wherein the waves connect at least three locations in the probe, each

said location being a transmission location or a receiving location and wherein at least one pair of connected locations is not collinear with any other pair of connected locations;

measuring a travel time for said received waves; and

deriving said acoustic bone velocity from said measurements.

66. A method of acoustic bone velocity determination, comprising:

transmitting at least one ultrasonic wave to a bone, which wave travels along the surface of the bone;

receiving said wave; and

analyzing a travel time of a particular frequency in said received wave, wherein said particular frequency is related to an expected thickness of a cortex of the bone.

67. A method according to claim 66, wherein said wave is transmitted as a narrow band wave at said particular frequency.

68. A method of calibrating a probe including a plurality of ultrasonic elements including at least one transmitter and one receiver, comprising:

coupling said probe to a plate having a first known acoustic velocity and measuring a first plurality of travel times between at least two pairs of said ultrasonic elements;

coupling said probe to a plate having a second known acoustic velocity and measuring a second plurality of travel times between at least two pairs of said ultrasonic elements; and

determining from said travel times at least two distances between pairs of said ultrasonic elements.

69. A method according to claim 68, wherein determining comprises determining at least one average vertical displacement of at least one of said pairs of elements.

70. A method of calibrating a probe comprising a plurality of ultrasonic elements including at least one transmitter and one receiver, the method comprising:

coupling said probe to a plate having a first known acoustic velocity and measuring a first plurality of travel times between at least two pairs of said ultrasonic elements;

coupling said probe to a plate having a second known acoustic velocity and measuring a second plurality of travel times between at least two pairs of said ultrasonic elements; and

determining from said travel times at least one average vertical displacement of at least

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one of said pairs of elements.

71. A method according to ~~any of claims 68-70~~ claim 68, wherein said plurality of ultrasonic elements comprises at least four ultrasonic elements.

72. A probe for acoustic bone velocity determination, comprising:

at least two ultrasonic elements, at least one of which comprises a transmitter and at least one of which comprises a receiver; and

a memory device attached to said probe, wherein calibration data for said probe are stored on said memory device,

wherein said calibration data comprises at least one vertical displacement of a path between two of said ultrasonic elements.

73. A probe for acoustic bone velocity determination, comprising:

at least two ultrasonic elements, at least one of which comprises a transmitter and at least one of which comprises a receiver; and

a memory device attached to said probe, wherein calibration data for said probe are stored on said memory device,

wherein said calibration data comprises a late cutoff time, after which received waves are ignored.

74. A probe according to claim 72 ~~or claim 73~~, wherein said calibration data comprises at least one distance between ultrasonic elements.

75. A probe according to ~~any of claims 72-74~~ claim 72, wherein said calibration data comprises at least one vertical displacement of an ultrasonic element.

76. A probe according to ~~any of claims 72-75~~ claim 72, wherein said calibration data comprises an acoustic velocity of a portion of the probe between at least one of said ultrasonic elements and a surface against which said probe is urged in use.

77. A method according to ~~any of claims 1-27~~ claims 1, wherein said end points are not collinear.

78. A method according to ~~any of claims 1-27 or 77~~ claims 1, wherein said end points are in a fixed

spatial relationship.

79. A probe according to any of ~~claims 29-54,~~ claim 29 wherein said ultrasonic elements are in a fixed spatial relationship.

add A1